STATE OF CALIFORNIA—CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

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MEMORANDUM

TO: K. D. Drachand, Chief
Mobile Sources Division

FROM: William V. Loscutoff, Chief
Monitoring and Laboratory Division

DATE: May 24, 1994

SUBJECT: ESTIMATED HYDROCARBON EMISSIONS OF PHASE II AND ONBOARD VAPOR RECOVERY SYSTEMS

On April 13, 1994, I forwarded a report, "Estimated Hydrocarbons Emissions of Phase II and Onboard Vapor Recovery Systems." Originally, we presented six cases to estimate the hydrocarbons emissions of Phase II with and without onboard vapor recovery system. We have added two cases. The first is onboard vehicles fueling at a service station with a Phase II balance system but without a PV valve. Second, we added a case where onboard vehicles are fueling in a service station with a Phase II assist system and a processor. Attached is the revised report with an amended date of May 24, 1994.

If you have questions, please feel free to call me at (916) 445-3742.

Attachment

cc: Jim Morgester, CD
Ken Kunaniec, Chairman, CAPCOA Vapor Recovery Technical Committee

State of California
California Environmental Protection Agency
Air Resources Board

Estimated Hydrocarbon Emissions of Phase II and Onboard Vapor Recovery Systems

April 12, 1994

Amended: May 24, 1994

Engineering Evaluation Branch
Monitoring and Laboratory Division

Estimated Hydrocarbon Emissions of Phase II and Onboard Vapor Recovery Systems

I. BACKGROUND

In the 1980s the Air Resources Board (ARB) staff prepared three documents (attached) that are still relevant references today[1]. The first document, "Report to the Legislature", contains emissions factors still in use today for dispensing facilities. The second document, "Docket Comments", contains our comments on the Onboard control regulations proposed by the U.S. Environmental Protection Agency (U.S. EPA) at that time. The document supports the contention that evaporative emissions and refueling must be dealt with separately. Two points mentioned in the Docket Comments bear emphasis:

(1) "We feel that the issue of excessive evaporative emissions is separate from and should be dealt with separately from fueling emissions. Excessive evaporative emissions can be effectively controlled with enlarged vehicle canisters and/or fuel volatility reductions. This can and should be done independently of the decision on controlling vehicle fueling emissions." (pp. 1-2)

(2)"... [I]f [Onboard refueling vapor recovery or ORVR] development is pursued it should be compatible with Phase II systems so that our California program will not be adversely affected and progress in other states will not be retarded." (p. 2)

The third document, "California Perspective", contains a strategy for coordinating efforts for hydrocarbon reduction using vapor recovery and evaporative controls, which connect to Onboard controls.

II. INTRODUCTION

Compatibility of Phase II and Onboard vapor recovery systems is still a crucial issue today, especially in light of the recent promulgation of U.S. EPA regulations requiring Onboard controls.

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[1] The references, in order of publication, are:

"A Report to the Legislature on Gasoline Vapor Recovery Systems for Vehicle Fueling at Service Stations (Phase II Systems)"; California Air Resources Board; March 1983 (referred to as "Report to the Legislature").

"Comments on 'Evaluation of Air Pollution Regulatory Strategies for the Gasoline Marketing Industry'", Docket #A-84-07; California Air Resources Board; November 13, 1984 (referred to as "Docket Comments").

"California Perspective on Controlling Gasoline Evaporative Emissions"; California Air Resources Board; March 1986 (referred to as "California Perspective").

The magnitude of hydrocarbon emissions can be estimated using empirical data, assumptions, and calculations based on model cases. We have developed a comparison of eight cases and operating conditions to illustrate the effects of using Phase II and Onboard technologies.

We have added two cases since the first edition published April 12, 1994; the added cases are Cases 4A and 5B, discussed below.

III. ANALYSIS

Nine figures, illustrating the basis for the eight cases in the table, are attached. The figure titled "All Cases" shows the features common to all eight cases. The titles for the other figures are "Case 1", "Case 2", etc.

All Cases:

All cases are analyzed for transfer and fugitive emissions, ignoring the effects of Phase I operations (emissions occurring when a cargo tank fills the underground storage tanks of the service station). Transfer emissions are assumed to occur only at the nozzle/fill-pipe interface (referred to simply as the "interface" below). "Fugitive emissions" is a collective term for emissions from the vent or any other leak path to the atmosphere at the dispensing facility, notably including the cargo tank fittings and dispenser plumbing.

All cases are based on a hot, summer, mid-day at a facility with a maximum allowed leak rate (a station which just passed a pressure decay test). Along with this general set of assumptions, each case is based on a set of additional specific assumptions which affect the calculated emissions estimates. Some alternative assumptions will be discussed, but only to explain the effects of the assumptions chosen. Other cases are beyond the scope of this report, which is to draw attention to problems and solutions for Phase II and Onboard compatibility issues.

As shown in the legend under the "All Cases" title, each case will be analyzed with specific assumptions about the presence or absence of the following dispensing facility and vehicle features, which will be explained in the discussion of the individual cases:

____ Phase II (____ balance ____ assist)

____ (+3/-8) "WC Vent Valve

____ Onboard

____ "Smart" Interface and Vent Valve[2]

Every case with Onboard vehicles assumes that 100% of the vehicles refueling at the dispensing facility are Onboard vehicles.

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[2] "Smart Interface and Vent Valve" is currently just an engineering concept in which a nozzle/fillpipe interface, based on commercial technology, allows the vapor recovery system to "sense" an Onboard vehicle and activate valves to limit air ingestion by the storage tank.

The schematic static pressure gauge in each case shows a typical storage tank pressure, given the assumptions. Such a pressure will not occur 100% of the time, and refinements of these estimates depend on further assumptions about the full correlation of pressure versus time for each case.

Summary of Cases 1 through 6

Important aspects of Phase II and Onboard and their interactions are summarized below. Detailed analyses of each case follow the summary.

Cases 1 through 3: No Onboard

When dispensing occurs to a conventional vehicle (Cases 1, 2, and 3), vapors are displaced out the fill-pipe. These cases represent the current situation in California (no Onboard vehicles and fueling at service stations without Phase II or at service stations with Phase II).

For Cases 1 and 2, although the vent pipe is open and with no pressure/vacuum (P/V) valve, the storage tank pressure is shown slightly positive because the vapors in the vent pipe are more dense than the air outside. The twelve feet of vent pipe above grade gives a pressure of 0.24 "WC at grade for a 30% concentration of gasoline vapors with an assumed molecular weight of 65.

For Case 3, the vent pipe has a P/V valve, and the nozzle vapor return line is check-valved to prevent the vapors in the tank from escaping to the atmosphere in between fuelings. The balance nozzle is assumed to provide an effective valve at the interface seal. For the conditions assumed, an air/vapor mixture (which is relatively warmer and richer in hydrocarbons) is returned to the air/vapor mixture in the storage tank (which is relatively cooler and leaner in hydrocarbons). Both condensation and thermal contraction reduce the specific volume of the air/vapor mixture in the storage tank. This dynamic process maintains a negative gauge pressure on the storage tank as shown on the schematic gauge.

Case 1 represents a service station without a Phase II system. Vapors are emitted at an emission rate of 8.4 pounds of hydrocarbon per 1,000 gallons (8.4 #/E3G) of liquid dispensed and represent 100% of uncontrolled transfer emissions. Fugitive emissions are estimated as 0.84 #/E3G.[3]

Cases 2 and 3 represent service stations equipped with Phase II systems in which 95% of the transfer emissions are recovered and returned to the storage tanks. Case 3 differs from Case 2 by the addition of a pressure/vacuum (PV) valve on the

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[3] Report to Legislature has 10.0 #/E3G transfer and 1.0 #/E3G fugitive. The 10.0 value has been reduced to 8.4 due to Bay Area Air Quality Management District (BAAQMD) field data subsequent to California regulations for lower RVP. For consistency, the fugitive emission value has been changed to 0.84.

vent pipe. The PV valve is a requirement in the proposed revisions to vapor recovery certification and test procedures.[4]

Cases 4A and 4B through 6: Onboard and Phase II Interactions

When dispensing occurs to an Onboard vehicle (Cases 4A, 4B, 5A, 5B, and 6), vapors are displaced to the Onboard canister. We will assume the Onboard system collects 95% of the transfer emissions. We assume here that the 5% lost is due to canister overflow and is thus not available to be recovered by Phase II. Vapors go to the vehicle canister and so do not return to the storage tank to balance its liquid volume lost. Because of this, air will enter the storage tank through the vapor return plumbing or system leaks unless appropriate technology is used.

Case 4A represents an Onboard vehicle fueling in a service station equipped with the current Phase II balance system[5]. Case 4A shows the vent pipe in its most common configuration in California. There is no P/V valve and there is no "smart" valve at the station to sense if the vehicle has an Onboard system. The fugitive emissions value for Case 4A is the same as for Case 1, which has no Phase II system. Because the Onboard canister takes the returned vapors in Case 4A, the liquid volume lost from the facility storage tank is not replaced by a blanket of saturated vapor; instead, air is drawn down the vent pipe, just as in Case 1.

Case 4B is similar to Case 4A, except that emissions are controlled by a Phase II balance system with a P/V valve. The interval between the pressure and vacuum settings can act as a buffer for pressure, volume, and temperature surges. This is because the air which is pulled into the system (when the Onboard system re-routes return vapors to the vehicle canister) enters the system through the P/V valve and

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[4] For Case 2, 95% control of 8.4 #/E3G results in 0.42 #/E3G *total* emissions. The report to the Legislature has Phase II controlling 90% of the vent pipe fugitive emissions. For Case 2, 90% reduction is assumed to apply to the 0.84 #/E3G assumed for Case 1, yielding fugitive emissions of 0.084 #/E3G, which is rounded to 0.08 #/E3G *fugitive emissions*. The *transfer emissions are then 0.34 #/E3G* (the difference of the total emissions minus the fugitive emissions).

At the March 29, 1994 fugitive emissions workshop held by ARB's Compliance Division, Aeroenvironment, contracted by the Western States Petroleum Association (WSPA), tested Phase II balance systems without and with P/V valves. ARB staff have witnessed the test and have discussed preliminary results with other experts. Based on such data and discussions, ARB staff believes that 0.02 #/E3G is an appropriate estimate of fugitive emissions for Case 3; the total emissions are then 0.36 #/E3G (the sum of the transfer emissions for Case 2, *0.34 #/E3G*, plus the fugitive emissions for Case 3, 0.02 #/E3G).

[5] The balance system relies on the pressure differential between the vehicle fuel tank and underground storage tank during refueling to remove the vapor from vehicle fuel tank. This system needs a tight seal at the fill-pipe and nozzle interface to prevent vapors from escaping into the atmosphere.

12 feet of vent pipe[6]. This may or may not suffice to provide an equilibration buffer against further fugitive emissions. Further study is needed involving actual Onboard vehicles at actual dispensing facilities with P/V valves. In the interim, the fugitive emissions value for Case 3 is retained.

Cases 5A and 5B represent an Onboard vehicle fueling in a service station equipped with a current Phase II assist system[7]. As with Cases 4A and 4B, the station has no "smart" valve. In Case 5A and 5B for an assist system, we have assumed that air will be pulled through the assist pump and pushed into the system vapor space. We assume that (unlike in Case 4B, where the equilibrium could buffer surges in the vent pipe) the liquid/vapor equilibrium will increase the system gauge pressure.

For Case 5A, calculations based on this assumption are given below in which the liquid/vapor equilibrium drives out fugitive emissions representing an efficiency loss of 35% of the uncontrolled transfer emissions; this yields a net efficiency loss of 30% of the uncontrolled transfer emissions compared to Case 3.

For Case 5B, the assumption of a 99% efficient vapor processor controlling fugitive emissions yields a total efficiency close to the total efficiency for Case 3.

The assumptions used in the calculations apply to the most common types of Phase II assist systems evaluated by ARB staff to date. Revised designs and new certification tests may justify assumptions which yield lower fugitive emissions for such assist systems.

Case 6 shows the ideal situation after new technology is developed for a "smart" interface between the nozzle and fill-pipe. Ideally, this yields nearly complete control of transfer and fugitive emissions.

Detailed Analyses of Cases 1 through 6

Case 1

Case 1 shows estimates of fugitive emissions and transfer emissions for dispensing with no air pollution controls, no Phase II and no Onboard. The transfer emission factor of 8.4 #/E3G is based on recent data for lower vapor pressures of newer fuel blends.

The fugitive emission factor of 0.84 #/E3G is due to air entering the storage tank via the vent pipe. The liquid/vapor equilibrium drives out fugitive emissions equal to about 12% of the uncontrolled transfer emissions. The emission factor due to

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6 It is assumed here that all air enters through the vent pipe. The validity of this assumption depends on the pressure integrity of the dispensing facility.

7 Assist system uses a pump to draw the vapor from the vehicle fill-pipe during fueling. This eliminates the needs for a tight seal at the fill-pipe and nozzle interface. Although less common and not shown, some assist systems place the assist pump at the top of the vent pipe.

equilibrium drive is less than in Case 5A, where it is estimated to be 2.9 #/E3G, about three times as high.

The difference in these fugitive emission factors is due to the difference in the path of entry through which air enters the storage tank:

(1) In Case 1, air enters through the open vent pipe and travels sixteen vertical feet before entering the storage tank proper. On the way, the liquid/vapor equilibrium drives a vapor/air mixture back up the vent pipe. Equilibration can occur in the vent pipe rather than in the vapor/air mixture saturated with hydrocarbon vapor at underground tank conditions.

In this case, equilibration does not necessarily force vapor/air mixture back out of the vent pipe and any other leak paths; instead the amount of air entering the system can be reduced.

(2) In Case 5A, air enters through the open, check-valved vapor return line at the nozzle and travels only six vertical feet before entering the storage tank proper. This is significantly different than the cases for balance systems, where any air enters through the vent pipe and must travel sixteen vertical feet to reach the storage tank. When liquid dispensing terminates, the vapor return valve closes so that equilibrium processes cannot drive the resulting vapor/air mixture back up the vapor return line. It is this mixture at the equilibrium concentration that is displaced from the vent pipe valve and any other leak paths by the equilibrium process when positive gauge pressure occurs in the facility vapor space.

In this case, equilibration forces vapor/air mixture back out of the vent pipe and any other leak paths. The amount of air entering the system can not be reduced because air is forced (by a pump across a check valve) into the vapor/air mixture saturated with hydrocarbon vapor at underground tank conditions.

The facility static gauge pressure in Case 1 is only slightly positive due to the column of vapors in the vent being denser than air.

Case 2

Case 2 shows estimates of fugitive emissions and transfer emissions for dispensing with Phase II control, no vent valve, and no Onboard. The transfer emission factor of 0.34 #/E3G is based on recent data for newer fuel blends and 95% transfer efficiency.[8]

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[8] The efficiency is based on the difference of the amount of transfer emissions collected minus the amount of fugitive emissions divided by the potential emissions from the refueling displacement. In this case, the equation is:

$$\frac{(8.4 - \text{transfer emissions}) - \text{fugitive emissions}}{8.4} \times 100\%$$

Compared to Case 1, the fugitive emission factor has dropped from 0.84 to 0.08 #/E3G. This is because the storage tank is blanketed with return vapors rather than air. As a result, equilibrium processes do not displace fugitive emissions. Diffusion and wind driven convection still account for non-zero fugitive emissions through the open vent pipe.

Once again, the facility static gauge pressure in Case 2 is only slightly positive due to the column of denser-than-air vapors in the vent.

Case 3

Case 3 shows estimates of fugitive emissions and transfer emissions for dispensing with Phase II control, with a (+3/-8)"WC vent valve, and no Onboard. The transfer emission factor of 0.34 #/E3G is the same as Case 2.

Compared to Case 1, the fugitive emission factor has dropped from 0.84 to typically 0.02 #/E3G. This is because the vent valve only allows the ingestion of air at negative gauge pressure and the positive gauge valve function limits diffusion and wind driven convection compared to an open vent pipe. A gravity- or spring-loaded vent valve is assumed here. Such valves, by design, do not achieve a complete seal when closed. Hence the 0.02 value rather than 0.00.

The facility static gauge pressure in Case 3 typically shows a negative reading due to the condensation of the warmer, richer vapors ingested from the vehicle tanks. Such vapors condense to the cooler, leaner equilibrium conditions in the storage tank.

Cases 4A and 4B

Case 4A shows estimates of fugitive emissions and transfer emissions for dispensing with balance type Phase II control and a vehicle with Onboard technology. The transfer emission factor of 0.42 #/E3G is based on the assumption that the Onboard technology has 95% efficiency. The fugitive emission factor is unchanged from Case 1, which has no Phase II system; the Phase II balance system in Case 4A cannot function as designed because vapors can not return to the storage tank.

Case 4B shows estimates of fugitive emissions and transfer emissions for dispensing with balance type Phase II control, with a (+3/-8)"WC vent valve, and a vehicle with Onboard technology. The transfer emission factor of 0.42 #/E3G is based on the assumption that the Onboard technology has 95% efficiency. The fugitive emission factor is unchanged from Case 3 as a gravity- or spring-loaded vent valve is still assumed. All fugitive emission control is assumed to be due to the P/V valve; the Phase II balance system in Case 4B can not function as designed because vapors can not return to the storage tank.

Cases 5A and 5B

Cases 5A and 5B show estimates of fugitive emissions and transfer emissions for dispensing with assist type Phase II control, with a (+3/-8)"WC vent valve, and a vehicle with Onboard technology. The transfer emission factor of 0.42 #/E3G again is based on the assumption that the Onboard technology has 95% efficiency.

Compared to Case 1, the fugitive emission factor has risen from 0.84 to typically 2.9 #/E3G[9]. This is due to the forced pumping of air into the underground tank as explained in the discussion for Case 1 above.

The facility static gauge pressure in Case 5A shows a positive reading due to the equilibrium drive working against closed valves in response to the forced introduction of air.

The assumptions and calculation supporting the fugitive emission factor estimate of 2.9 #/E3G are provided below:

Assume

(1) the concentration of fugitive emissions is 6.77 pounds of hydrocarbon per 1000 assuming:[10]

(a) 30% equilibrium hydrocarbon concentration

(b) average molecular weight of 65 for hydrocarbons (C4.5)

(2) the concentration of fugitive emissions depends on a dynamic equilibrium affected by several independent variables, including, but not limited to:

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[9] The term, 2.9#/E3G, assumes that there are no hydrocarbon processors such as an incinerator, carbon bed adsorber, and chiller at the vent stack to reduce hydrocarbon emissions. The use of a processor would reduce emissions at an assumed efficiency of 99% as shown in Case 5B.

[10] Pressure integrity testing has shown that pressurization by equilibrium processes is measurable within minutes. The 30% concentration assumption is a typical mid-range value for field sampling and analysis by ARB and BAAQMD staff. For comparison, the nomograph in API Bulletin 2513 (February 1959, Appendix 5, page 43) provides a "book value" of 29.1 % for a 7.8 RVP gasoline at 65 °F. The typical carbon number of 4.5 is from BAAQMD staff work with field samples. The value 6.77 is calculated as follows:

$$30\% \times \left[\frac{65\#\ HC}{385\ ft^3}\right] \times \left[\frac{ft^3}{7.481\ gal}\right] \times \left(\frac{1{,}000\ gal}{1{,}000\ gal}\right) = \left(\frac{6.77\ \#\ HC}{1{,}000\ gal}\right)$$

(a) Reid vapor pressures and temperatures of liquids in the storage tank and the vehicle tank[11]

(b) ratio of the volume of air returned divided by the volume of liquid dispensed

(c) pressure integrity of and convection through the vapor recovery system

(3) the vehicle tank vapor space volume equilibrates rapidly to 8.4 pounds of hydrocarbon per 1,000 gallons by evaporation or condensation across the liquid/vapor interface.

Calculate

(1) the volume of fugitive emissions which results from equilibration of 1,000 gallons of ingested air:

Note: The first term below is the ratio of the emitted fugitive volume divided by the volume of air ingested. The volume fraction of vapor in the final equilibrated volume at zero gauge pressure is C%. This is the mole fraction at equilibrium. Consider that the volume fraction of the ingested air in the final equilibrated volume at zero gauge pressure is (100% - C%). Now, the volume of vapor/air mixture (at C%) which will leak to atmosphere is the product of the ingested air volume and the ratio of the two volume fractions. In the following example, C = 30.

$$\left(\frac{30\%}{100\% - 30\%}\right) \times 1000 \text{ gallons air} = 428.6 \text{ gallons vapor solution}$$

(2) the mass of fugitive emissions which results from equilibration of 1,000 gallons of ingested air:

$$428.6 \text{ gallons vapor solution} \times \frac{6.77 \text{ pounds HC}}{1000 \text{ gallons vapor solution}} = 2.90 \text{ pounds HC}$$

[11] The measured concentration of the fugitive emissions can be higher than the book value based only on the Reid vapor pressure and the temperature of the storage tank liquid. For the case considered, the warmer, richer air/vapor mixture from the vehicle tank is not returned to the cooler, leaner mixture in the storage tank because we have assumed 100 % Onboard vehicles.

(3) the fugitive emission factor due to equilibration of the ingested air volume per 1,000 gallons of liquid dispensed to an Onboard vehicle:

$$2.90 \text{ pounds HC} \div 1000 \text{ gallons dispensed} = \frac{2.90 \text{ pounds HC}}{1000 \text{ gallons dispensed}}$$

(4) the efficiency loss as percent of uncontrolled transfer emissions:

$$\frac{2.9 \text{ pounds}}{1000 \text{ gallons}} \div \frac{8.4 \text{ pounds}}{1000 \text{ gallons}} = 36\%$$

Note: In consideration of the variability in our field values for concentration, if the concentration is 10% instead of 30%, the results of the two calculations above are:

(3) 0.25 pounds per 1000 gallons (fugitive emission factor) and

(4) 3.1% (efficiency loss as a percentage of transfer emissions).

For Case 5B, the assumption of a 99% efficient vapor processor controlling fugitive emissions yields a fugitive emission factor of 0.03 pounds per 1000 gallons and a total efficiency of 94.7%.

Case 6

Case 6 shows estimates of fugitive emissions and transfer emissions for dispensing with Phase II control, with a (+3/-8)"WC vent valve, a vehicle with Onboard technology, a "smart" interface between the dispensing facility nozzle and the vehicle fill-pipe, and a solenoid controlled valve on the vent pipe. The transfer emission factor of 0.42 #/E3G is based on the assumption that the Onboard technology is 95% efficient.

Compared to Case 1, the fugitive emission factor has dropped from 0.84 to typically 0.02 #/E3G. This is because the solenoid controlled vent valve only allows the ingestion of air at negative gauge pressure and the positive gauge valve is not perfect, but has a small leak.

As in Case 3, the facility static gauge pressure in Case 6 shows a negative reading due to the condensation of the typically warmer, richer vapors ingested from the vehicle tanks. Such vapors condense to the cooler, leaner equilibrium conditions in the storage tank. Compared to Case 3, a much less negative reading is shown for Case 6 on the assumption that the "smart" interface, described below, will modulate facility gauge pressure more precisely.

Currently, the "smart" interface and vent valve is just an engineering concept; however it is based on the use of commercial technology. The concept involves a nozzle spout and vehicle fill-pipe which are fabricated so that a signal is generated when they come together. One type of signal is generated by an interface with an Onboard vehicle. Another type of signal is generated by an interface with a non-Onboard (current type) vehicle. The vapor recovery system closes the vapor return valve for an Onboard vehicle and opens the vapor return valve for a non-Onboard vehicle.

This achieves the best combined effect for the simultaneous application of both Phase II and Onboard technologies. The vapor recovery system ingests vapor while dispensing to non-Onboard vehicles but does not ingest air while dispensing to Onboard vehicles.

IV. RECOMMENDATIONS

An emissions summary for all cases is shown in Table 2. The lowest emissions shown for Onboard cases are for Case 4B (Phase II balance system, P/V valve, and Onboard) and Case 6 (Phase II, "smart" interface and vent valve, and Onboard). As 95% of California's dispensing facilities currently are controlled by balance systems, the impact of Onboard refueling at such facilities appears to be minimal if balance systems retain their predominance in California. The incompatibility demonstrated between Onboard and some types of assist systems should be further studied to determine if the smart interfaces or other means can be used to overcome the problem.

We recommend that any California regulations concerning Onboard controls be structured to ensure that Phase II and Onboard systems are compatible; only Case 4B, 5B and Case 6 show technical compatibility. Our recommendation provides compatibility for a 20 year phase-in for Onboard vehicles in California and provision for visiting vehicles from the other 49 states if California prohibits Onboard vehicles.

Summary of Estimates of

Emissions from Refueling with Phase II and Onboard Vapor Recovery Systems

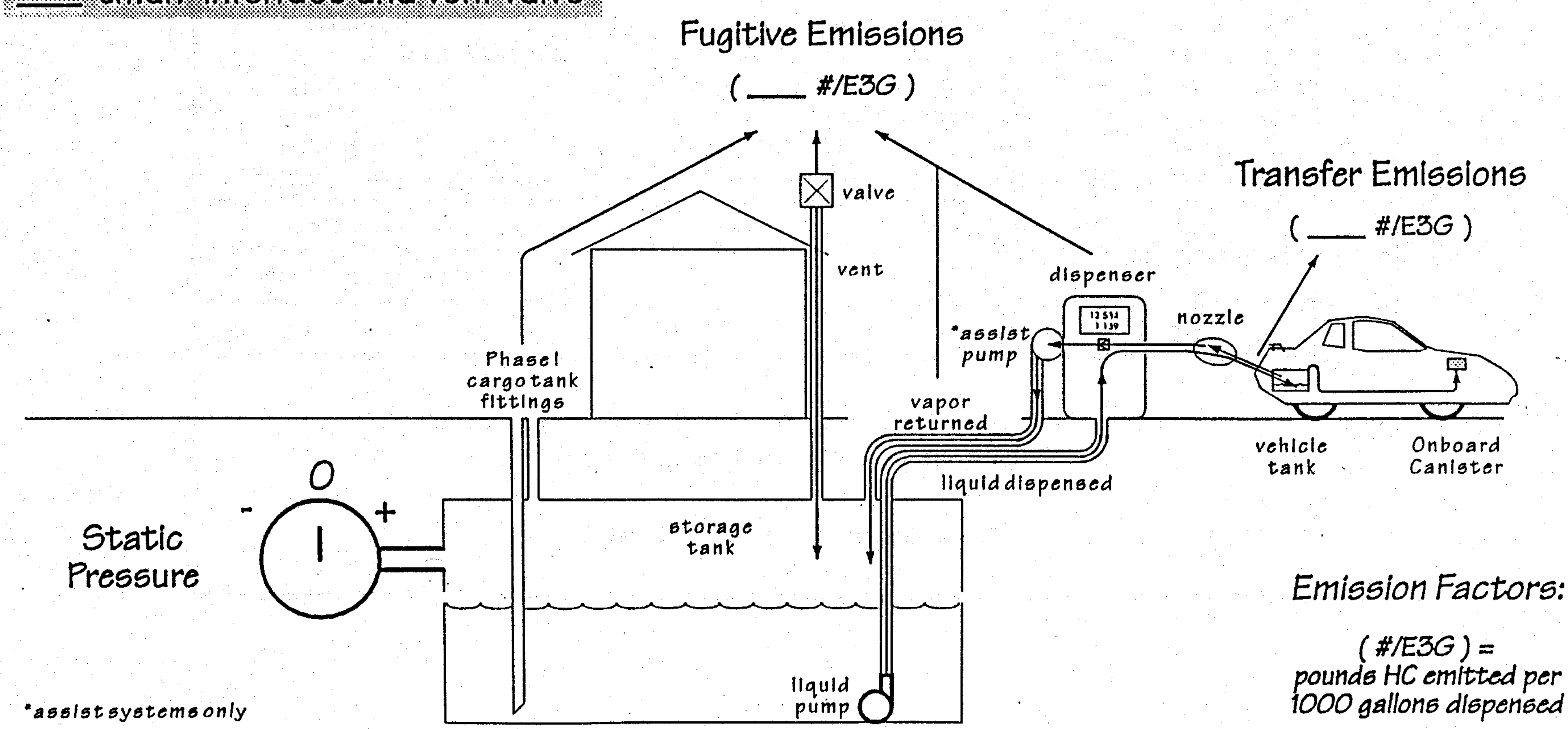
Case Number	1	2	3	4A	4B	5A	5B	6
Operating Conditions								
Conventional	yes	no	no	no	no	no	no	no
Phase II Vapor Recovery	no	yes	yes	yes	yes	yes	yes	yes
Balance	no	yes	yes	yes	yes	no	no	yes
Assist	no	no	some	no	no	yes	yes	yes
Processor	no	no	some	no	no	no	yes	no
(+3/-8) "WC Vent Valve	no	no	yes	no	yes	yes	yes	no
"Smart" Interface and Vent Valve	no	no	no	no	no	no	no	yes
Onboard Vapor Recovery	no	no	no	yes	yes	yes	yes	yes
Emissions (pounds per 1,000 gallons)								
Transfer Emissions	8.4	0.34	0.34	0.42	0.42	0.42	0.42	0.42
Fugitive Emissions	0.84	0.08	0.02	0.84	0.02	2.90	0.03	0.02
Total Emissions	9.24	0.42	0.36	1.26	0.44	3.32	0.45	0.44
Efficiency (per cent)	NA	95.0	95.7	85.0	94.8	60.5	94.7	94.8

All Cases:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and
Vehicle Features:

a busy, hot, summer, mid-day at
a facility with good pressure integrity

____ Phase II (____ balance ____ assist)
____ (+3/-8) "WC Vent Valve
____ Onboard
____ "Smart" Interface and Vent Valve

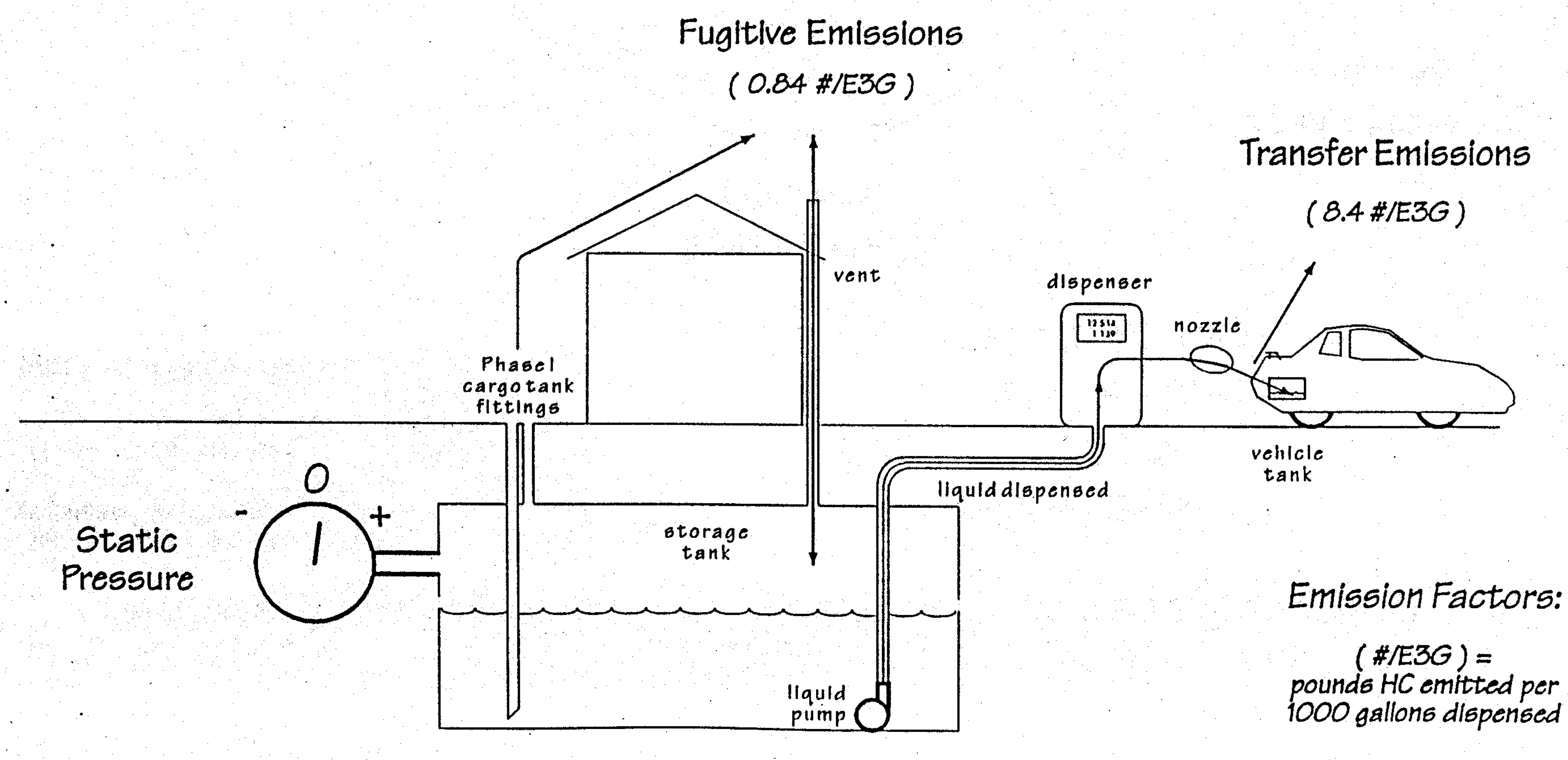


Case 1:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and
Vehicle Features:

a busy, hot, summer, mid-day at
a facility with good pressure integrity

no Phase II
no Vent Valve
no Onboard



Emission Factors:

(#/E3G) =
pounds HC emitted per
1000 gallons dispensed

Case 2:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and Vehicle Features:

a busy, hot, summer, mid-day at a facility with good pressure integrity

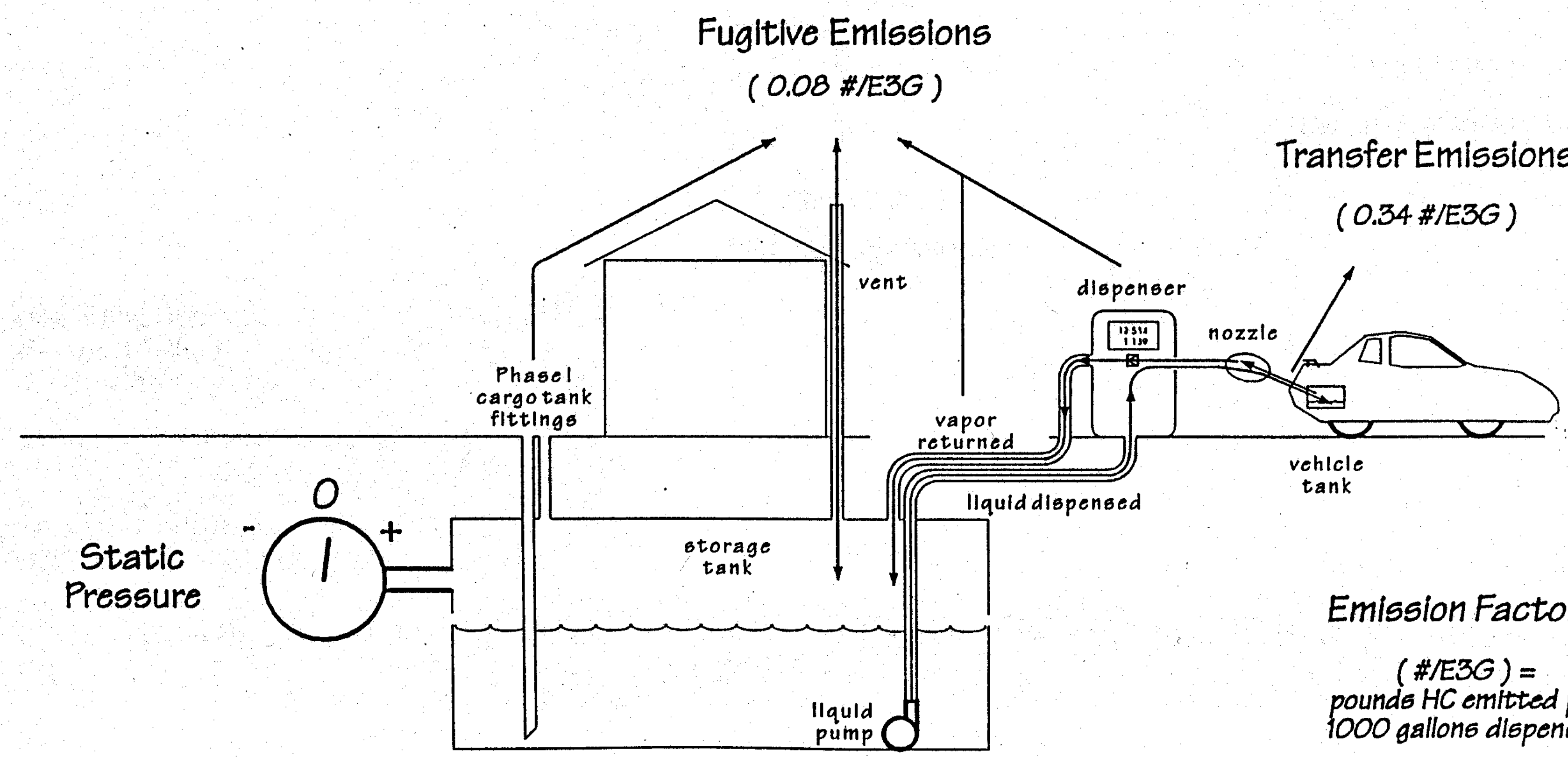
with Phase II (*with* balance)

System Efficiency

95.0%

System Emissions

(0.42 #/E3G)



Emission Factors:

(#/E3G) = pounds HC emitted per 1000 gallons dispensed

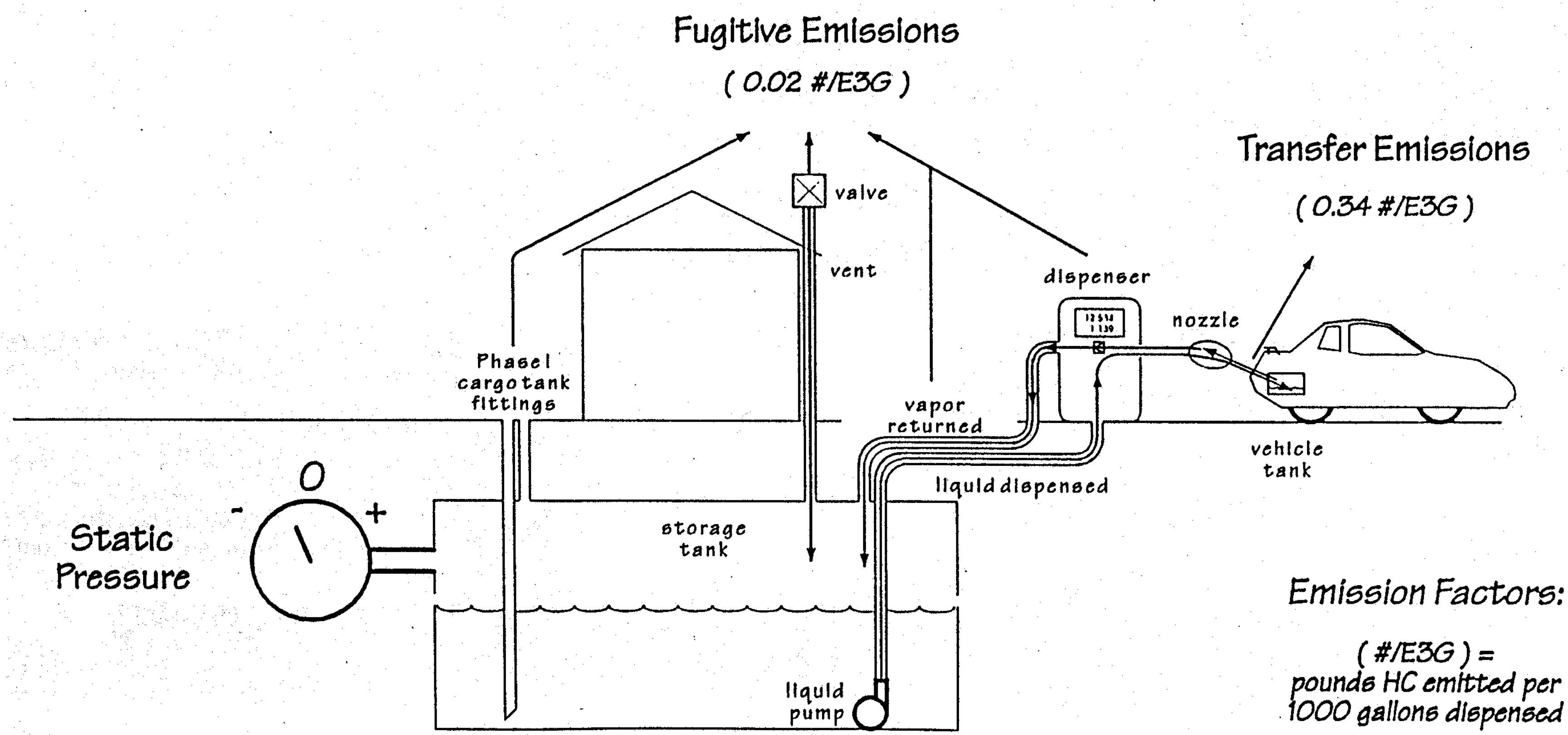
Case 3:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and
Vehicle Features:

a busy, hot, summer, mid-day at
a facility with good pressure integrity

with Phase II (*with* balance)
with (+3/-8) "WC Vent Valve

System Efficiency
95.7%
System Emissions
(0.36 #/E3G)



Emission Factors:

(#/E3G) =
pounds HC emitted per
1000 gallons dispensed

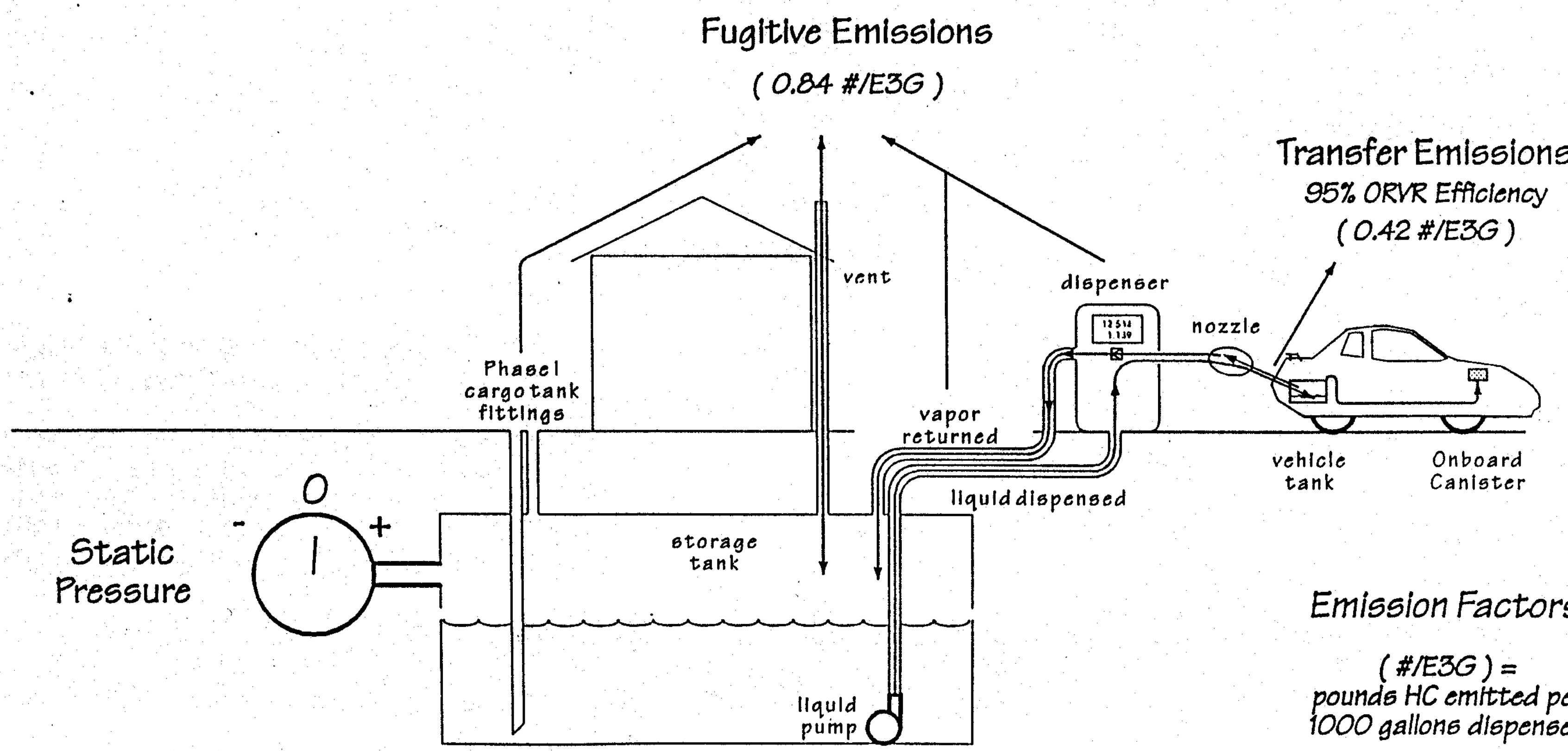
Case 4A:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and
Vehicle Features:

a busy, hot, summer, mid-day at
a facility with good pressure integrity

with Phase II (*with* balance)
with Onboard

System Efficiency
85.0%
System Emissions
(1.26 #/E3G)



Emission Factors:

(#/E3G) =
pounds HC emitted per
1000 gallons dispensed

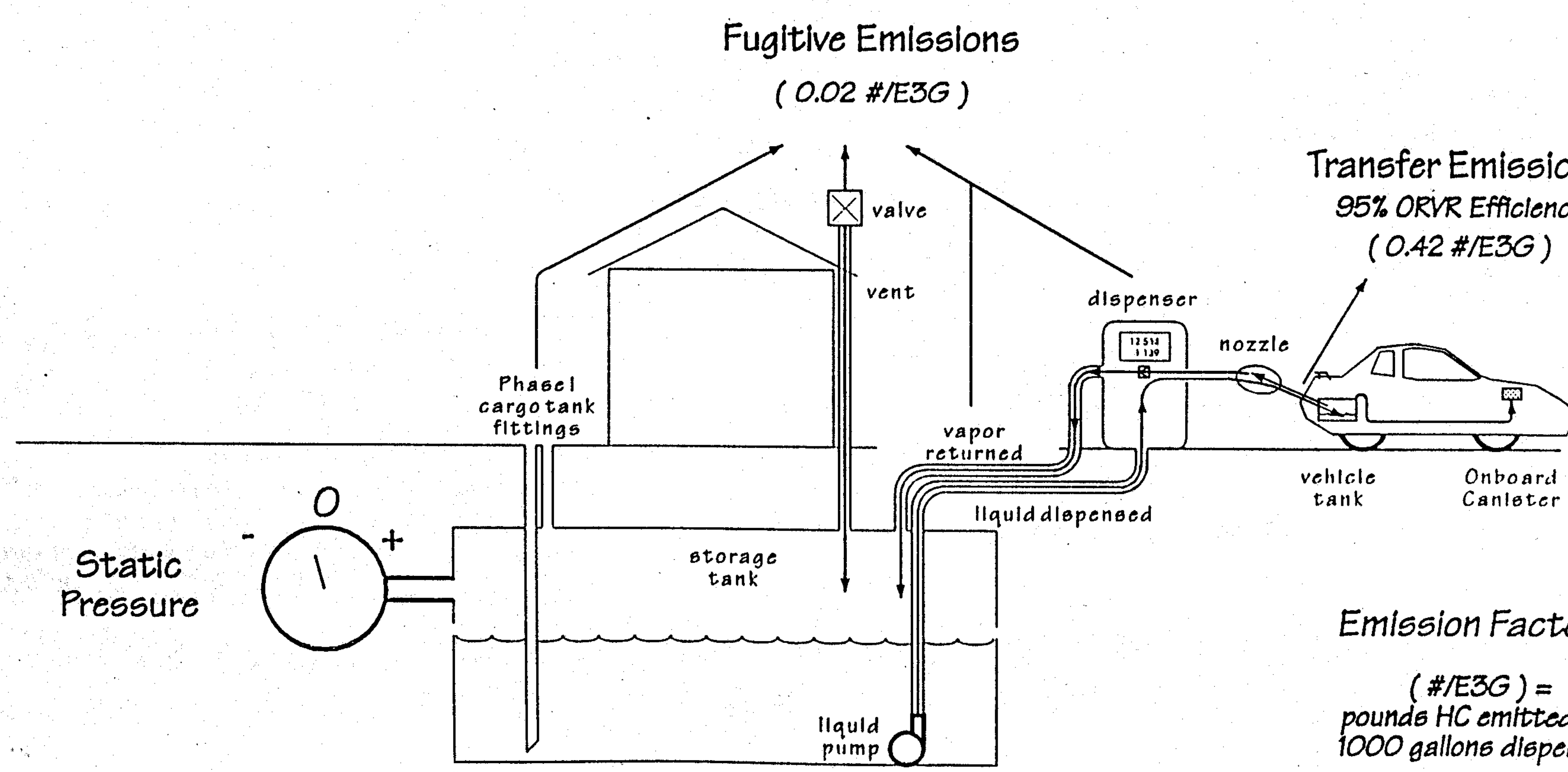
Case 4B:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and Vehicle Features:

a busy, hot, summer, mid-day at a facility with good pressure integrity

with Phase II (*with* balance)
with (+3/-8) "WC Vent Valve
with Onboard

System Efficiency
94.8%
System Emissions
(0.44 #/E3G)



Emission Factors:

(#/E3G) =
pounds HC emitted per 1000 gallons dispensed

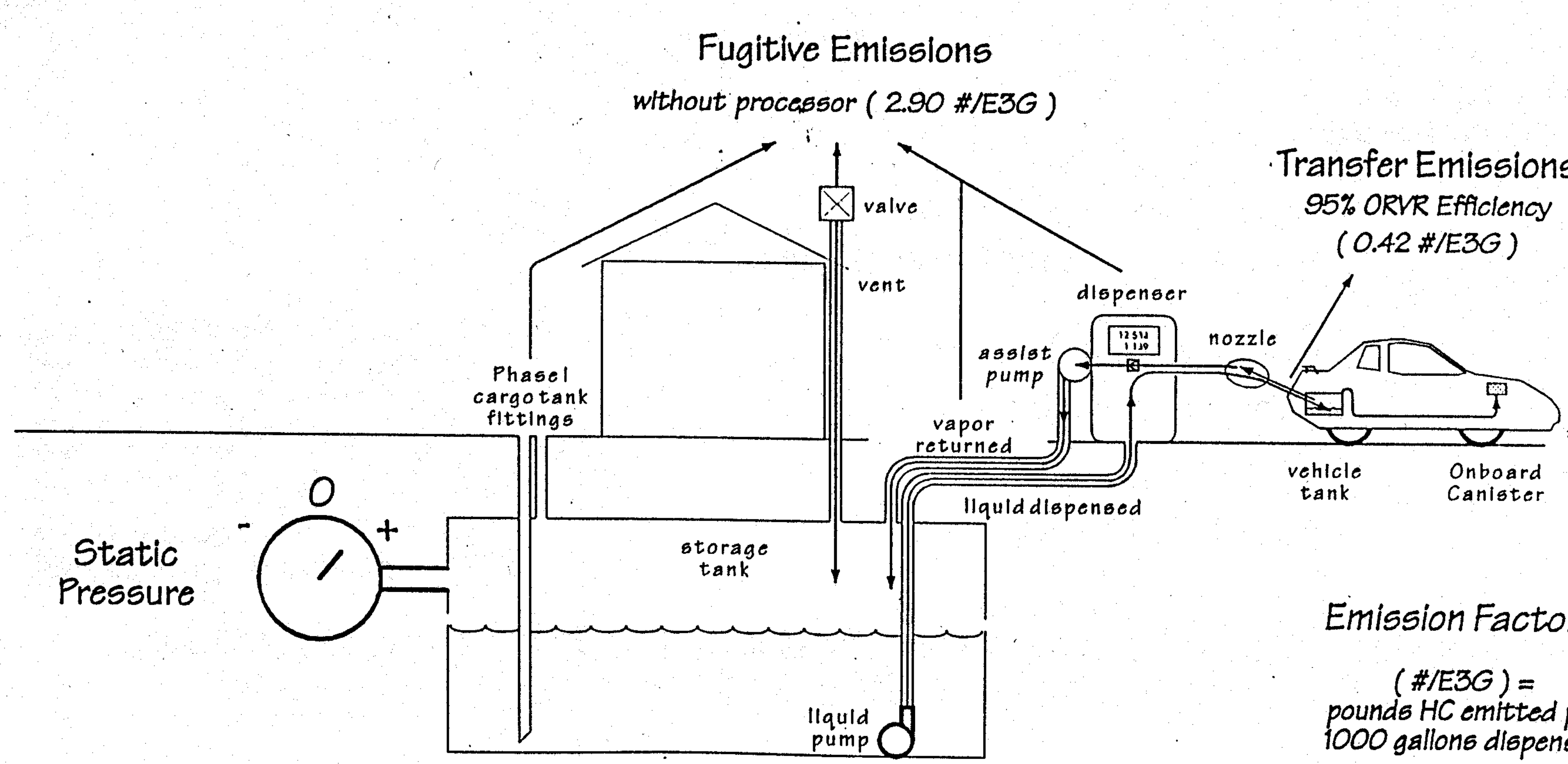
Case 5A:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and Vehicle Features:

a busy, hot, summer, mid-day at
a facility with good pressure integrity

with Phase II (*with* assist)
with (+3/-8) "WC Vent Valve
with Onboard

System Efficiency
60.5%
System Emissions
(3.32 #/E3G)



Emission Factors:

(#/E3G) =
pounds HC emitted per
1000 gallons dispensed

Case 5B:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and
Vehicle Features:

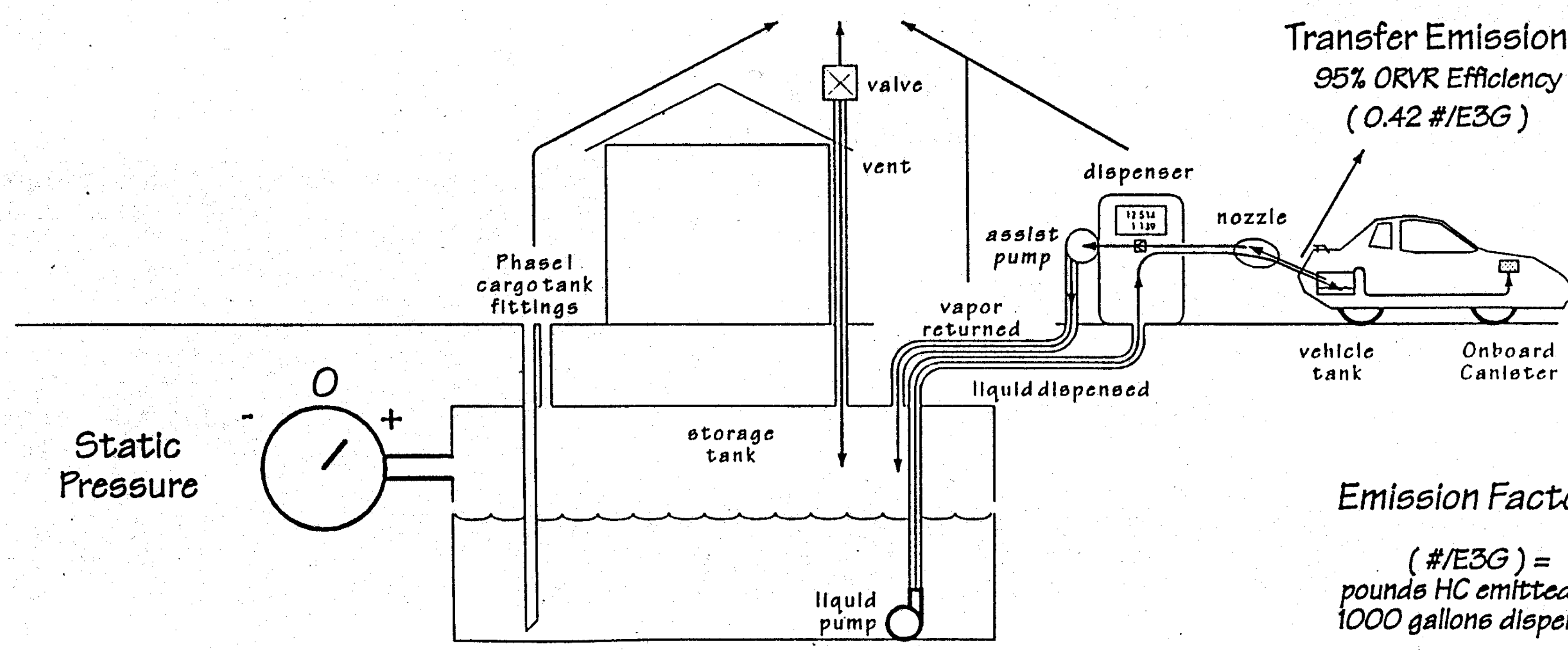
a busy, hot, summer, mid-day at
a facility with good pressure integrity

with Phase II (*with* assist)
with (+3/-8) "WC Vent Valve
with Onboard

System Efficiency
94.7%
System Emissions
(0.45 #/E3G)

Fugitive Emissions
with processor (0.03 #/E3G)

Transfer Emissions
95% ORVR Efficiency
(0.42 #/E3G)



Emission Factors:

(#/E3G) =
pounds HC emitted per
1000 gallons dispensed

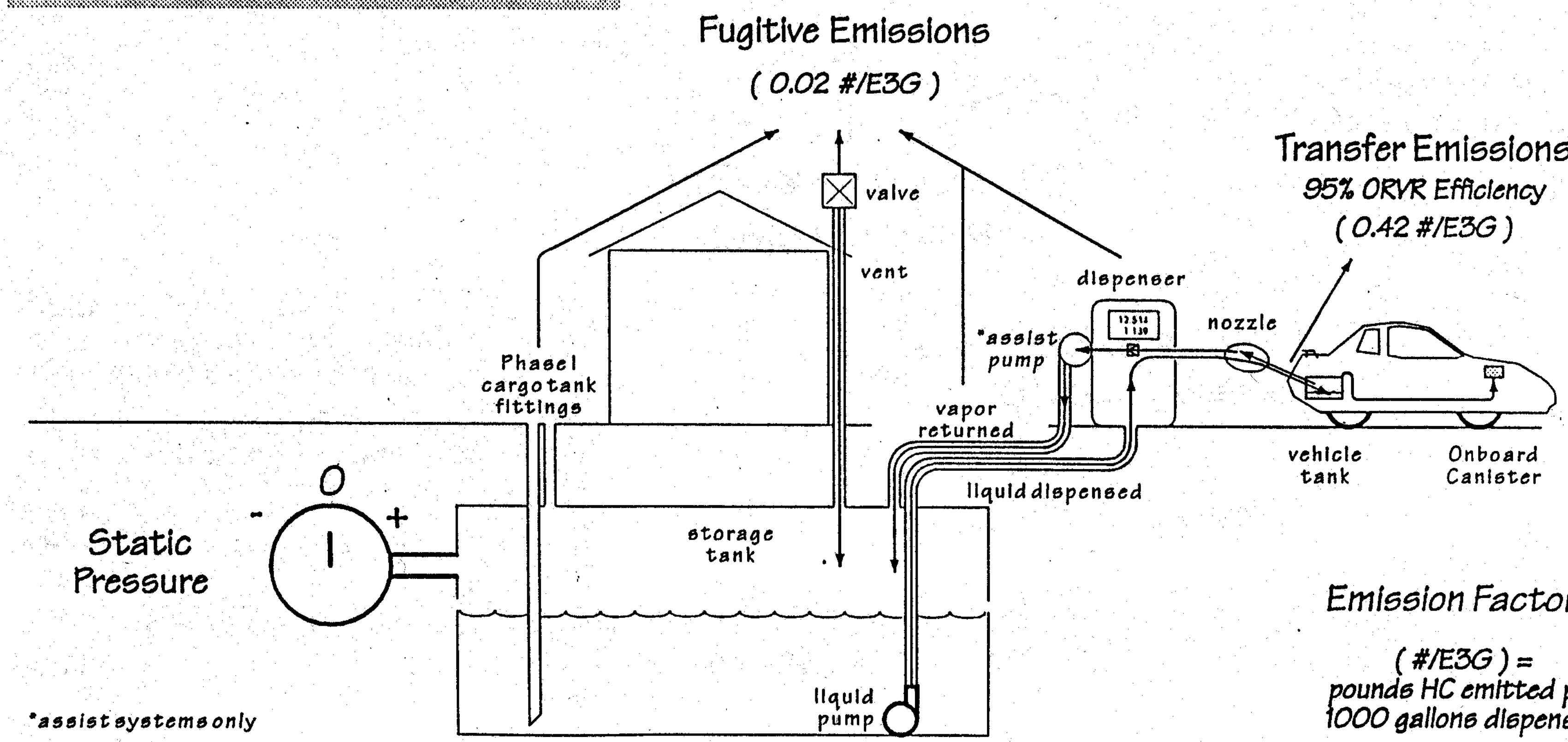
Case 6:
Transfer Emissions and Fugitive Emissions due to Refueling

Dispensing Facility and
Vehicle Features:

a busy, hot, summer, mid-day at
a facility with good pressure integrity

with Phase II (*with* balance *or* assist)
with (+3/-8) "WC Vent Valve
with Onboard
with "Smart" Interface and Vent Valve

System Efficiency
94.8%
System Emissions
(0.44 #/E3G)



*assist systems only

Emission Factors:

(#/E3G) =
pounds HC emitted per
1000 gallons dispensed